PATENT SPECIFICATION

(11) 1 572 094

(21) Application No. 11024/76 (22) Filed 18 Mar. 1976

(23) Complete Specification Filed 18 Mar. 1977

(44) Complete Specification Published 23 Jul. 1980

(51) INT. CL.[3] H03K 17/00

(52) Index at Acceptance
H3T 2B1 2B6 2M 2W2 3D 3V 4D CX

(19)

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1 572 094

(54) SEMICONDUCTOR SWITCHING CIRCUIT

(71) We, KODAK LIMITED, a company registered under the law of England, of Kodak House, Station Road, Hemel Hempstead, Hertfordshire, do hereby declare the invention for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:
ductor circuits for energising high voltage, moderate current electrical power loads.

Thyristors are often employed to energise electrical power loads from an alternating current supply. When this energisation is to occur at mains frequency, a single thyristor may be used. In this mode of operation, the thyristor employed will cease to conduct automatically as the alternating current mains voltage reverses polarity during each cycle.

If, however, the load is to be energised at a frequency other than mains frequency, a pair of thyristors may be employed connected as a commutating pair. The power required to energise the load is obtained from a direct current supply. The thyristors are triggered alternately by applying trigger pulses at the desired energisation frequency to the gate terminals of each thyristor. As one thyristor conducts, electrical energy is transferred through a commutation capacitor to turn off the other thyristor. In this way alternate conduction of the thyristors is obtained. The load to be driven, connected in series with one of the thyristors, is energised at the frequency of the trigger pulses applied to the gate terminals of the thyristors.

The use of thyristors connected as a commutating pair has certain disadvantages. If the commutation fails two alarm conditions can arise: a) Both thyristors can be turned on simultaneously giving a 'locked-up' condition. In this fault condition power is fed continuously to the load. b) The load may not be energised for every applied trigger pulse. Also, interference spikes can cause incorrect triggering at the sensitive gate inputs of the thyristors. Design of this type of circuit becomes more difficult with inductive loads, since both commutation and trigger characteristics vary with temperature, pulse rise time and device characteristics.

According to the present invention there is provided apparatus for energising one or more electrical power loads, comprising electrical power supply means for supplying electrical power to energise the or each load, trigger pulse supply means for supplying electrical trigger pulses at a preselected frequency and of a preselected duration, one or more transistor switching means actuable in response to the electrical trigger pulses fed thereto from the trigger pulse supply means to cause energisation of the or each load by the electrical power supply means in the form of energisation pulses which have a frequency and a duration equal to that of the said preselected trigger pulses, and one or more electrical isolation means between the or each transistor switching means and the trigger pulse supply means to prevent power from the electrical power supply means from passing to the trigger pulse supply means while allowing trigger pulses to pass to the or each transistor switching means from the trigger pulse supply means wherein the trigger pulse supply means is arranged to operate at an electrial potential up to 30 V DC and the or each transistor switching means is arranged to operate at an electrical potential greater than 150 V DC.

The present invention will now be described, by way of example, with reference to the drawings accompanying the Provisional Specification in which:-

Figure 1 is a diagram representing apparatus for energising an electrical power load from a power source in accordance with the present invention;

Figure 2 is a diagram representing apparatus for energising two electrical power

loads in accordance with the present invention;

Figure 3 represents the voltage across the loads A and B of Figure 2 during a typical switching cycle; and

Figure 4 is a diagram showing apparatus similar to that shown in Figure 2 with the components shown in greater detail.

Referring to Figure 1, there is shown apparatus for energising an electrical power load from a power supply which produces a potential V_1. A signal source 2 produces trigger signals which are fed to an amplifier 4. The amplified trigger signals emanating from amplifier 4 are shaped by a pulse shaper 6 to form trigger pulses which are fed to transistor driving means comprising a driver transistor TR2, and thence via diodes D_1 and D_2 to a switching transistor TR1. The trigger pulses are amplified by a driver transistor TR2 to a level sufficient to cause switching transistor TR1 to conduct and thereby energise the electrical load 8 from a power supply 10. Switching transistor TR1 will only conduct for the duration of each trigger pulse received at its base terminal from the pulse shaper 6. Hence, the power supply 10 will energise the electrical load 8 by an energisation pulse caused by a trigger pulse from pulse shaper 6 being received at the base terminal of switching transistor TR1. In this manner it is possible to control the frequency and duration of energisation of the electrical load 8 by preselecting the frequency and duration of the trigger pulses emanating from the pulse shaper 6. Diodes D_1 and D_2 are provided between the switching transistor TR1 and the driver transistor TR2 to prevent power from the power supply 10 from passing to the trigger portion of the circuit while allowing the trigger pulses to pass from the driver transistor TR2 to switching transistor TR1. Hence the potential V_1 may be greater than the collection-emitter breakdown voltage of transistor TR2. Also, diodes D_1 and D_2, together with the driver transistor TR2 are chosen to ensure that the trigger pulses arriving at the base terminal of the switching transistor TR1 have short rise and fall times, typically less than 1 μS. These fast rise and fall trigger pulses, together with the 'blocking' action provided by diodes D_1 and D_2, enable high voltage power transistors to be utilized in the switching circuit in combination with a trigger circuit operating from a direct current supply of a potential normally found in semiconductor circuits, e.g. <30V. This 'blocking' action prevents power from the power supply 10 from passing to the trigger portion of the circuit. With present transistor technology, electrical loads of up to approximately 700V working can be reliably switched at any pulse rate, by means of the circuit hereinbefore described. It will be understood that, as transistor technology progresses, the switching of higher voltage electrical loads at any pulse rate can be envisaged by employing apparatus as shown in Figure 1. The use of transistors for switching such loads has distinct advantages over the use of thyristors connected as a commutating pair.

a) There is minimal risk of the switching device being 'locked-on' or failing to trigger as the transistor, under normal operation, will conduct for every applied trigger pulse, and only for the duration of the applied trigger pulse.

b) The switching power transistors are relatively insensitive at the base terminals and are unlikely to be triggered by interference spikes arriving at the base terminals.

If it is desired to energise more than one electrical load in a predetermined phase relationship then a circuit as shown in Figure 2 may be employed.

In Figure 2 there is shown apparatus for energising two loads A and B at any preselectable frequency, duration and phase relationship by means of a single trigger pulse source. The supply power for the switching and the trigger portions of the circuit are derived by known means.

The trigger signals are derived from any suitable source 12, and are fed to an amplifier 14. The output signals from the amplifier 14 are fed to two similar pulse shapers 16 and 18. Each pulse shaper may comprise a set pulse delay module and a set pulse duration module. By using pulse shapers of this type, any desired trigger pulse duration and trigger pulse phase delay may be preselected for energizing electrical loads A and B. Although one amplifier 14 is shown feeding both pulse shapers 16 and 18 there could alternatively be provided one amplifier for each pulse shaper.

The output pulses from pulse shapers 16 and 18 are fed to driver transistors TR5 and TR6 respectively and then, via diodes D_3, D_4 and D_5, D_6 respectively to switching transistors TR3 and TR4 respectively. The operation of both portions of the circuit; i.e. the portion for electrical load A and that for electrical load B, is as that previously described with reference to Figure 1. Hence, the electrical loads A and B may be energised with any preselected phase displacement and for any preselected time period, an example of which is shown by Figure 3.

A circuit of the form shown in Figure 2 can be used for driving a vibratory conveyor system. A circuit suitable for use in this system is shown in Figure 4. The electrical loads A and B are 20 Henry electromagnetic loads which are utilized as pulsating magnets to drive the conveyor system. Fast switching protection diodes D_7 and D_8 are connected across the electrical loads A and B. The 300V direct current supply to energise the electrical

loads A and B is obtained from a constant voltage transformer 20 and conventional rectification components 22. A constant voltage transformer is used as this type of device has a 'soft' start, i.e. the eventual secondary winding voltage is not attained for approximately 4 Hz after connection of a 50 Hz alternating current mains voltage to the primary winding. This type of start limits switch on surge currents to the switching circuit. Spike protection 24 is provided for the switching circuit by the connection of a varistor disc and a fast rresponse pulse capacitor across the 300V direct current supply. The trigger circuit operates from a 15V direct current supply and the trigger signals are derived from a feedback coil 12' induced by a permanent magnet attached to the conveyor assembly (not shown) giving a self oscillatory action. The pulse shapers 16' and 18' are constructed from standard 555 type integrated circuit timers which are adjustable to set the duration of the trigger pulses.

The diodes D_3'-D_6' are included between the driver and switching transistor to provide the 'blocking' action previously described with reference to Figure 1.

The switching transistors TR3' and TR4' are triple diffused silicon high voltage power transistors, Westinghouse type 5206. General Electric type A114 diodes are utilized for diodes D_3'-D_6'.

WHAT WE CLAIM IS:

1. Apparatus for energising one or more electrical power loads comprising electrical powr supply means for supplying electrical power to energise the or each load, trigger pulse supply means for supplying electrical trigger pulses of a preselected duration, one or more transistor switching means actuable in response to the electrical trigger pulses fed thereto from the trigger pulse supply means to cause energisation of the or each load by the electrical power supply means in the form of energisation pulses which have a frequency and duration equal to that of the said preselected trigger pulses, and one or more electrical isolation means between the or each transistor switching means and the trigger pulse supply means to prevent power from the electrical power supply means from passing to the trigger pulse supply means while allowing trigger pulses to pass to the or each transistor switching means from the trigger pulse supply means wherein the trigger pulse supply means is arranged to operate at an electrical potential up to 30 V DC and the or each transistor switching means is arranged to operate at an electrical potential greater than 150 V DC.

2. Apparatus according to claim 1 wherein the or each electrical isolation means comprises two or more semiconductor diodes series connected between the or each transistor switching means and the trigger pulse supply means.

3. Apparatus according to claim 2 wherein the or each electrical isolation means comprises two semiconductor diodes.

4. Apparatus according to claim 1, 2 or 3 wherein the trigger pulse supply means comprises one or more pulse shaping means.

5. Apparatus according to claim 4 wherein the or each pulse shaping means comprises an adjustable timer to set the duration of the trigger pulses.

6. Apparatus according to any one of the preceding claims wherein the trigger pulse supply means is provided with one or more transistor driving means.

7. Apparatus according to claim 6 wherein the electrical power supply means has an electrical potential which exceeds the collector-emitter breakdown voltage of the or each transistor driving means.

8. Apparatus according to any one of the preceding claims wherein the trigger pulse supply means is provided with one or more electrical signal amplifying means.

9. Apparatus according to any one of the preceding claims wherein the or each transistor switching means is of a triple diffused silicon type.

10. Apparatus according to any one of the preceding claims wherein the trigger pulse supply means comprises one or more electrical signal delay means.

11. Apparatus according to any one of the preceding claims wherein the or each electrical power load is/are of an inductive type.

12. Apparatus according to any one of the preceding claims wherein the electrical power supply means comprises a constant voltage transformer and spike protection means connected across the output terminals of the electrical power supply means.

13. Apparatus according to claim 1 substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

14. A vibratory conveyor apparatus comprising one or more electromagnets for imparting vibratory motion to the conveyor and comprising apparatus according to any one of the preceding claims for energising the or each electromagnet.

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Agent for the Applicants.

Printed for Her Majesty's Stationery Office, by Croydon Printing Company Limited, Croydon, Surrey, 1980. Published by The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.

1572094 PROVISIONAL SPECIFICATION

3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

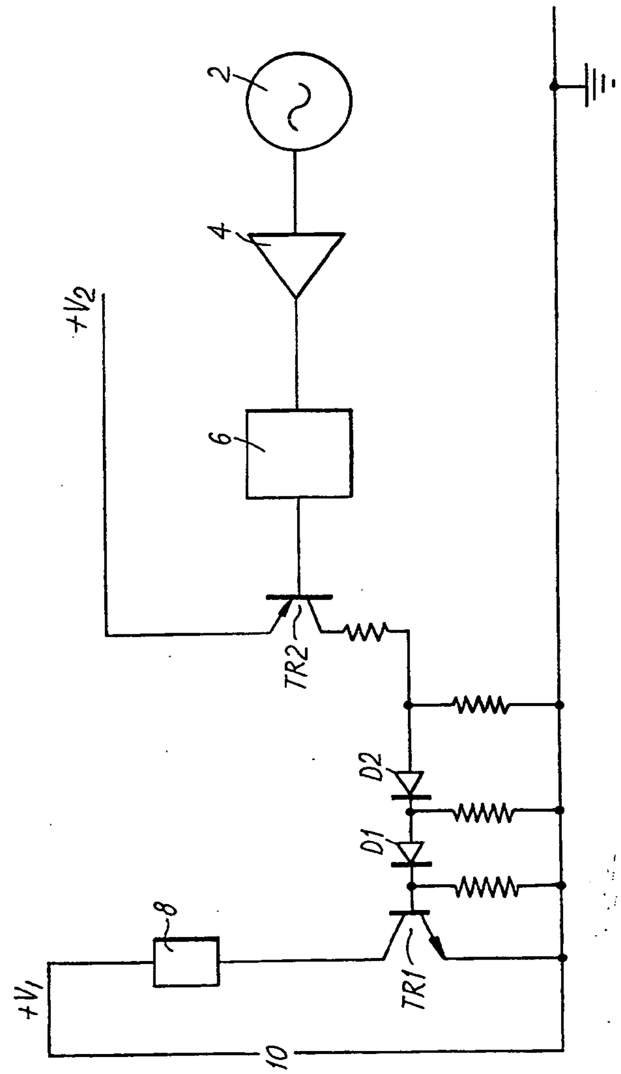

FIG. 1

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Sheet 2

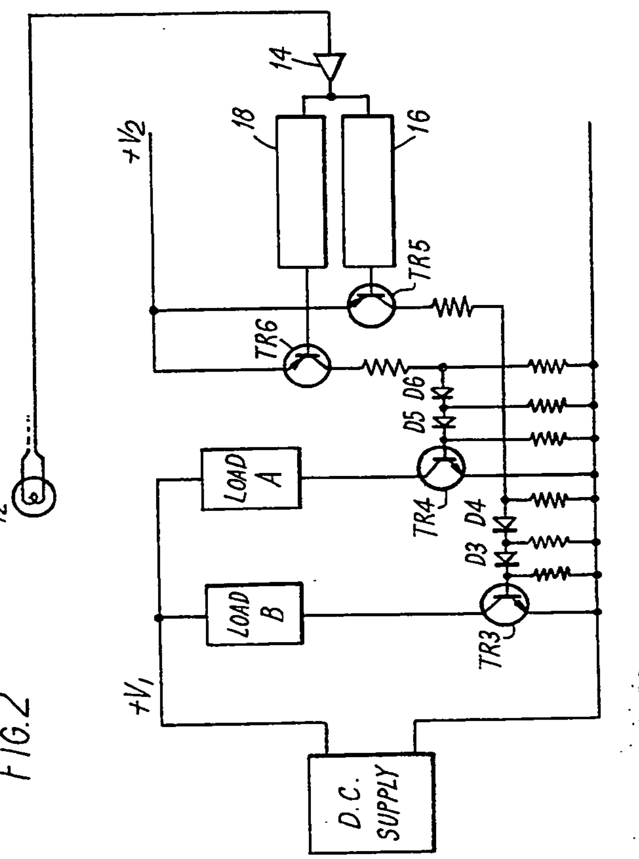

FIG.2

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3 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 3

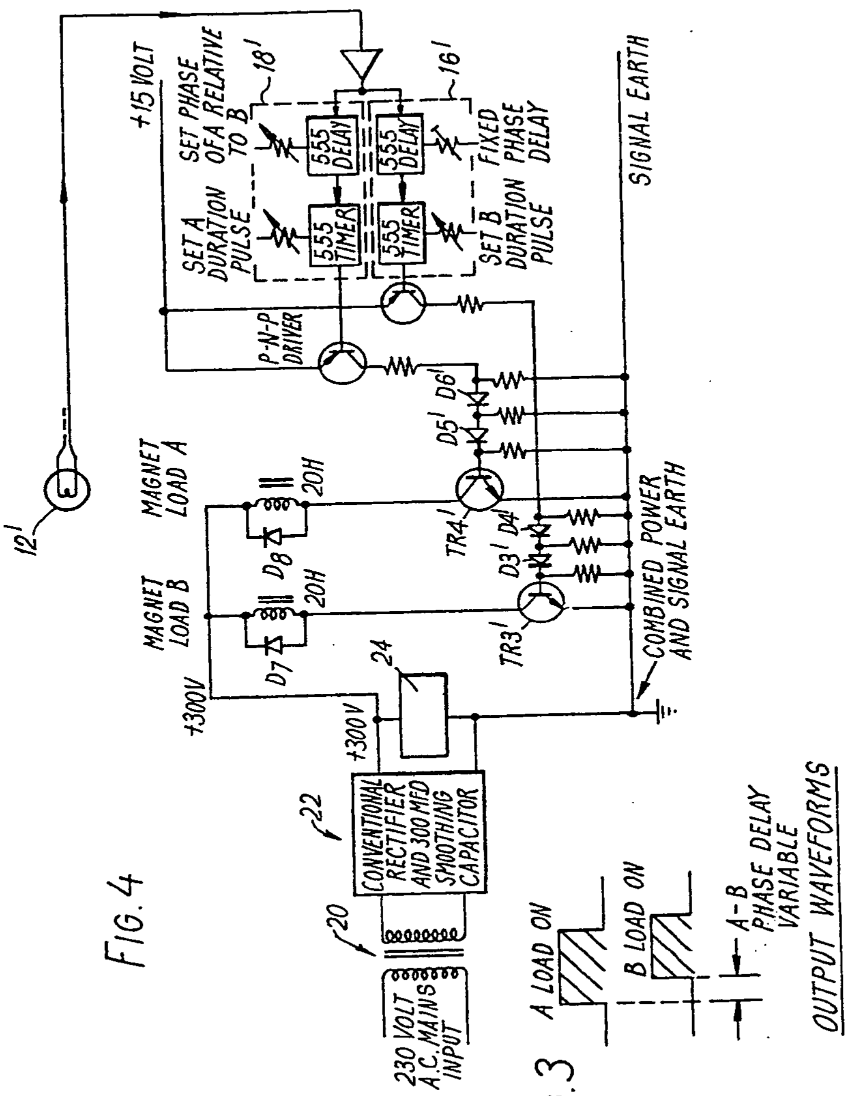

FIG. 4

FIG. 3